

# **METHOD AND APPARATUS USING MULTIPLE SENSORS IN A DEVICE WITH A DISPLAY**

## REFERENCE TO RELATED APPLICATION

The present invention claims priority from a  
5 U.S. Provisional application having serial number  
60/218,748, filed on July 17, 2000 and entitled "METHOD  
AND APPARATUS USING MULTIPLE SENSORS IN A MOBILE  
DEVICE."

## BACKGROUND OF THE INVENTION

10 The present invention relates to devices  
with displays. In particular, the present invention  
relates to computing and mobile devices.

Mobile devices, such as personal  
information managers (PIMs), cellular telephones,  
15 pagers, watches, and wearable computers typically  
include one or more buttons or touch screens through  
which the mobile device receives explicit  
instructions from the user. For example, the user  
can press buttons to explicitly instruct the device  
20 to enter a full-power mode, activate an application,  
or scroll through an image on the display.

Although the devices are responsive to  
information provided through such explicit  
instructions, they are generally not responsive to  
25 information that is present in the manner in which  
the device is being handled by the user. For example,  
the devices do not automatically enter a full-power  
mode, even when the user is holding the device in a

manner that is consistent with wanting to use the device.

The reason these devices are not responsive to such handling information is that they typically  
5 are not equipped with the sensors needed to detect the information nor with the software needed to interpret the information.

Because these devices are generally not responsive to the manner in which the user is holding  
10 the device, the user is forced to enter explicit instructions into the device to achieve various functions. In light of this, mobile devices are needed that can sense how they are being handled in order to perform certain background functions that  
15 expand the functionality of the mobile device without requiring the user to perform any additional actions.

#### SUMMARY OF THE INVENTION

In a device having a display, at least one sensor signal is generated from a sensor in the  
20 device. One or more context values are then generated from the sensor signal. The context values indicate how the device is situated relative to one or more objects. At least one of the context values is then used to control the operation of one or more  
25 aspects of the device.

The invention includes several aspects. In one aspect, an image on a display is scrolled at a rate that is based on the difference between a current tilt angle and a tilt angle when tilt

scrolling was activated. A further aspect of the invention adjusts the contrast of a display based on the tilt angle of the display.

Other aspects of the invention control the power mode of the device based on whether it is being handled, its orientation, and/or whether it is being gestured toward.

Still further aspects of the invention activate applications based on the device being in a particular orientation while being held by the user.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the components of a mobile device under one embodiment of the present invention.

FIG. 2 is a bottom view of a mobile device of one embodiment of the present invention.

FIG. 3 is a front view of the mobile device of FIG. 2.

FIG. 4 is a back view of the mobile device of FIG. 2.

FIG. 5 is a left side view of the mobile device of FIG. 2.

FIG. 6 is a right side view of the mobile device of FIG. 2.

FIG. 7 is a graph of distance between a user and a mobile device as a function of proximity sensor levels.

FIG. 8 is a block diagram of components used to practice several embodiments of the present invention.

FIG. 9 is a graph of left-right tilt versus forward-back tilt showing those tilt angles that activate an audio device.

FIG. 10 is a front view of a mobile device in a portrait orientation.

FIG. 11 is a front view of a mobile device in a landscape orientation.

FIG. 12 is a chart showing the display orientations for various combinations of forward/back tilt and left/right tilt.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a block diagram of a mobile device 200, which is an exemplary environment for embodiments of the present invention. Mobile device 200 includes a microprocessor 202, memory 204, input/output (I/O) components 206, and a communication interface 208 for communicating with remote computers or other mobile devices. In one embodiment, the afore-mentioned components are coupled for communication with one another over a suitable bus 210.

Memory 204 is implemented as a non-volatile electronic memory such as a random access memory (RAM) with a battery back-up module (not shown) such that information stored in memory 204 is not lost when the general power to mobile device 200 is shut

down. A portion of memory 204 is preferably allocated as addressable memory for program execution, while another portion of memory 204 is preferably used for storage, such as to simulate storage on a disk drive.

5           Memory 204 includes an operating system 212, application programs 214, and an object store 216. During operation, operating system 212 is preferably executed by processor 202 from memory 204. Operating system 212, in one preferred embodiment, is  
10 a WINDOWS® CE brand operating system commercially available from Microsoft Corporation. Operating system 212 is preferably designed for mobile devices, and implements database features that can be utilized by applications 214 through a set of exposed  
15 application programming interfaces and methods. The objects in object store 216 are maintained by applications 214 and operating system 212 at least partially in response to calls to the exposed application programming interfaces and methods.

20           Communication interface 208 represents numerous devices and technologies that allow mobile device 200 to send and receive information. The devices include wired and wireless modems, satellite receivers and broadcast tuners to name a few. Mobile  
25 device 200 can also be directly connected to a computer to exchange data therewith. In such cases, communication interface 208 can be an infrared transceiver or a serial or parallel communication

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left/right tilt sensor 260, a proximity sensor 262 consisting of an infrared transmitter 264 and an infrared receiver 266, a digital compass 284, and a gravity switch 282. The sensing signals from the  
5 infrared receiver 266, left/right tilt sensor 260, forward/back tilt sensor 258, digital compass 284, and gravity switch 282 are provided through respective amplifiers 270, 272, 274, 285 and 287 to analog inputs of PIC microprocessor 252. These  
10 analog inputs are connected to analog-to-digital converters within PIC microprocessor 252. In other embodiments, the sensors provide a digital output and thus are connected to digital inputs on the microprocessor.

15 In the embodiment of FIG. 1, touch sensors 254 and 256 are provided to a separate peripheral interface controller microprocessor 276 which converts the touch signals into digital values and provides the digital values to PIC microprocessor  
20 252. In other embodiments, touch sensors 254 and 256 are connected directly to analog or digital inputs in PIC microprocessor 252 instead of being connected to PIC 276 or are connected to processor 202.

PIC microprocessor 252 also includes a  
25 connection to the power bus of mobile device 200, which is shown as connection 278 in FIG. 1. PIC microprocessor 252 also includes a connection to a power switch 280, which enables PIC microprocessor 252 to turn mobile device 200 on and off. Note that

PIC microprocessor 252 always receives power and, under one embodiment, is able to control which of the sensors receives power at any one time. This allows PIC microprocessor 252 to manage power consumption by only sending power to those sensors that it anticipates will need to be active.

Under one embodiment, PIC microprocessor 252 continuously samples the sensors and transmits packets representing the state of these sensors at a rate of approximately 400 samples per second through serial port 250. In some embodiments, samples are reported at lower speeds to conserve power and processing resources. Some sensors may be reported at different sampling rates than others (e.g. tilt may be updated more frequently than touch).

Under one embodiment, touch sensor 254 is a capacitive touch sensor that is divided into two regions. In other embodiments, it is also possible to implement this sensor with a single detector pad. This touch sensor is spread across the back and sides of mobile device 200. This is shown in more detail in FIGS. 4-6 which show a back, left side view and right side view of the outside of mobile device 200. In FIGS. 4, 5, and 6, touch sensor 254 is shown as two regions 300 and 302. Region 300 extends from the left side to the back of mobile device 200 and region 302 extends from the right side to the back of mobile device 200. When a user touches either section 300 or 302, the capacitance associated with the touched



section changes indicating that the user has touched the device. Note that although the touch sensors are shown on the exterior of the device in the embodiment of FIGS. 4-6, in other embodiments, the touch sensor  
5 is located beneath an outer covering of the device.

Touch sensor 256 is shown in FIG. 3, which is a front view of mobile device 200. In the embodiment of FIG. 3, touch sensor 256 is located on the left bezel of display screen 304. In other  
10 embodiments, touch sensor 256 is located on the outer casing on the front portion of mobile device 200, but not necessarily on bezel 306 of mobile device 200.

In some embodiments, the touch sensors described above are realized using a plurality of  
15 independent touch sensors that each provides a separate touch signal. In other embodiments, the touch sensors are replaced with position sensors that indicate the location where the user is touching the device. Those skilled in the art will recognize that  
20 additional touch sensors may be added to the mobile device within the scope of the present invention.

Left/right tilt sensor 260 and forward/back tilt sensor 258 are shown as a single dotted element 308 in FIG. 3. These tilt sensors are embedded  
25 within the casing of mobile device 200 and in one embodiment are located at a point about which users typically pivot mobile device 200 when tilting the device. Note that the tilt sensor's position within the mobile device is unimportant as it senses only

the angle of its physical attitude with respect to gravity. The sensor's angular position within the device is important.

Under one embodiment, an Analog Devices  
5 ADXL05 two-axis linear accelerometer is used for tilt sensors 258 and 260. Such a sensor detects forward/backward tilt, shown by arrows 310 of FIG. 5, and left/right tilt, shown in the bottom view of FIG. 2 as arrows 312. The sensor also responds to linear  
10 accelerations, such as those resulting from shaking the device. Typically, the tilt sensor has a response curve both in the forward/back direction and left/right direction with the form:

$$\text{Angle} = \sin^{-1} \left( \frac{T - T_c}{k} \right) \quad \text{EQ. 1}$$

15 where T is the tilt sensor value,  $T_c$  is the sensor value at  $0^\circ$  tilt, and k is a gain parameter. In embodiments where the sensor cannot detect the sign of the gravity vector, it is unable to determine if the user is holding the device with the display  
20 facing up or down. Gravity switch 282 of FIG. 1 is thus provided in some embodiments to indicate whether the display is facing the ground. In other embodiments, a three-axis accelerometer is used to provide the sign of the gravity vector.

25 In addition, the tilt sensors do not respond to rotation about an axis running from the front to the back of the mobile device. Thus, the tilt sensors are unable to sense the spinning of the

mobile device on its back when laid on a flat table. Digital magnetic compass 284 of FIG. 1 is thus provided in some embodiments to indicate this type of rotation. In other embodiments, solid state gyros  
5 are used instead of the compass.

When present, gravity switch 282 and digital compass 284 are also internal to mobile device 200. They are not shown in FIG. 3 to reduce the complexity of FIG. 3.

10 Note that the additional input devices of FIG. 1 do not all have to be present under the present invention. Different embodiments of the invention will use different numbers of and different combinations of these additional sensors. Further,  
15 additional sensors may be added without affecting the functions of the sensors discussed in the present application.

Transmitter 264 and receiver 266 of proximity sensor 262 are shown in FIG. 3. In the  
20 embodiment of FIG. 3, transmitter 264 is shown below and to the right of receiver 266, and both the transmitter and receiver are located at the top front of mobile device 200.

Under one embodiment, a timer 265 drives  
25 transmitter 264 at 40 kilohertz and transmitter 264 is an infrared light emitting diode with a 60° beam angle. Under such embodiments, receiver 266 is also an infrared receiver that is capable of operating at the same frequency as transmitter 264. The light

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produced by transmitter 264 bounces off objects that are near mobile device 200 and the reflected light is received by receiver 266. Receiver 266 typically has an automatic gain control such that the strength of the received signal is proportional to the distance to the object.

FIG. 7 shows a response curve for one embodiment of the proximity sensor. In FIG. 7, the sensor value is shown along horizontal axis 702 and the actual distance to the object is shown along vertical axis 704. The graph of FIG. 7 is divided into three ranges. Range 706 extends from a distance of approximately 27 centimeters to infinity and indicates that no objects are within range of mobile device 200. Range 708 extends from approximately 7 centimeters to 27 centimeters and indicates that at least one object is within range of mobile device 200. Readings in third range 710, which extends from 7 centimeters to 0 centimeters, are considered to be close to mobile device 200. The response curve of FIG. 7 is described by the following equation:

$$Z_{cm} = \frac{k}{\left( \frac{p}{p_{max}} - c \right)^{\alpha}} \quad \text{EQ. 2}$$

where  $z_{cm}$  is the distance in centimeters to the object,  $p$  is the raw proximity reading,  $p_{max}$  is the maximum sensor reading,  $c$  is a constant,  $\alpha$  is a

nonlinear parameter (.77 in one embodiment), and k is a gain factor.

Under one embodiment, the power consumed by proximity sensor 262 is limited by pulsing transmitter 264 a few times a second when the user is out of range, or by reducing the duty cycle of timer 265.

In other embodiments, IR receiver 266 generates a digital signal instead of the analog signal shown in FIG. 1. The digital signal provides a representation of the transmitted signal. However, as the distance between the device and the user increases, the number of errors in the digital signal increases. By counting these errors, PIC 252 is able to determine the distance between the user and the device.

FIG. 8 provides a block diagram of the software components of one embodiment of the present invention. In FIG. 8, a context information server 800 receives the sensor data from serial port 250 of FIG. 1.

Context information server 800 acts as a broker between the sensor values received by the microprocessor 252 and a set of applications 802 operating on mobile device 200. Context information server 800 continuously receives sensor data packets from PIC 252, converts the raw data into a logical form, and derives additional information from the sensor data.

Applications 802 can access the logical form of information generated by context information server 800 either by polling a block of shared memory 804 in which context information server 800 stores the logical form information, or alternatively by asking context information server 800 to provide a specific piece of information via a system event message when a specific sensor value changes.

In addition, applications can post certain context information with context information server 800 so that it may be shared with other applications. Such posting is described in greater detail in context with one embodiment of the present invention described below.

In FIG. 8, a first in/first out memory stack 806 is also provided that stores a history of past states for mobile device 200. These past states are used in certain embodiments of the present invention as described further below.

Tables 1, 2, 3 and 4 below provide lists of the context variables that can be generated by context information server 800. In the description column of each table, specific values for the variables are shown in italics. For example, the DISPLAYORIENTATION variable can have values of flat, portrait, landscape left, landscape right, or portrait upside down.

Group	Context Variable	Description
Touch	Holding&Duration	Whether or not the user is holding the device and for how long
	TouchingBezel&Duration	Whether user is touching screen bezel and for how long

Table 1

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Group	Context Variable	Description
Tilt/ Accelerometer	TiltAngleLR, TiltAngleFB	Left/Right and Forward/Back tilt angles in degrees
	DisplayOrientation ,Refresh	<i>Flat, Portrait, LandscapeLeft, LandscapeRight, or Portrait- UpsideDown.</i> A Refresh event is posted if apps need to update orientation
	HzLR, MagnitudeLR, HzFB, Magnitude FB	Dominant frequency and magnitude from FFT of tilt angles over the last few seconds
	LookingAt, Duration	If user is looking at display
	Moving & Duration	If device is moving in any way.
	Shaking	If device is being shaken
	Walking, Duration	If user is walking

Table 2



Group	Context Variable	Description
Proximity	Proximity	Estimated distance in cm to proximal object
	ProximityState, Duration	<i>Close, InRange, OutOfRange, AmbientLight</i> (when out-of-range and bright ambient light is present)

Table 3

Group	Context Variable	Description
Other	Scrolling	If user is currently scrolling (posted by scroll app)
	VoiceMemoGesture	If recording a voice memo. (posted by voice recording app)

Table 4

5

The context variables of Table 1 are generated based on signals from the touch sensors, those in Table 2 are generated based on tilt sensors, those in Table 3 are generated based on the proximity sensors, and those in Table 4 are posted by other applications and are not generated directly from the sensor data.

10

The sensors described in FIG. 1 have many novel uses under the present invention. Each of these uses is described below.

ACTIVATING AN AUDIO RECEIVER

5           Many applications on mobile devices activate an audio receiver to receive an audio input that is further processed. For example, the audio signal can be recorded, can be used as input to a speech recognition system, or can be transmitted.

10           Typically, devices have activated their audio receiver based on the user pressing a button or activating a particular application. Thus, the user must physically manipulate a button or keyboard in order to activate and deactivate the audio receiver.

15           The present invention provides a means for automatically activating an audio receiver based on how the user is holding the input device.

20           In its most basic form, the present invention activates the audio receiver based on a proximity sensor that senses when the input device is close to the user. In more complex embodiments, the input device must also be held by the user before the audio receiver will be activated; this prevents accidental activation of the audio receiver when the device is in a purse or briefcase. In the embodiment of FIGS. 2-6, the user is considered to be holding the device when the touch sensors on the side and back of the device are activated.

In still more complex embodiments, the user must also tilt the device before the audio receiver will be activated. For instance, in one embodiment, the user must hold mobile device 200 in an almost vertical position. Under one embodiment, the angle of tilt must be within a specific range. Since users typically tilt an input device to the left and back when making the gesture associated with wishing to speak into the input device, both left/right tilt and forward/back tilt can be examined to determine if the tilt is proper. These tilt angles correspond to the approximate angle at which one would hold a device such as a mobile phone when speaking into it. Several ranges of tilt signals can be used, such that tilting will be recognized if the device is held either in the left or the right hand.

This can be seen in FIG. 9, which shows left/right tilt along horizontal axis 1000 and forward/back tilt along vertical axis 1002. A block 1004 indicates the acceptable ranges for left/right and forward/back tilt for activating the audio receiver.

The conditions of being held, having the device in close enough proximity, and having the device properly tilted must all be met for at least .1 seconds before the audio receiver is activated under one embodiment of the present invention.

In embodiments that use proximity, touch, and tilt to determine when to activate the audio

receiver, the audio receiver is deactivated if any one of these criteria stops being met. For example, if the user stops holding the device, or the user takes the device away from their mouth, the audio  
5 receiver would be deactivated.

Under some embodiments, to assist the user in knowing when the audio receiver is active, a sound is emitted by mobile device 200 when the receiver is activated. Another sound is then emitted when the  
10 audio receiver is deactivated. In still further embodiments, a separate sound is provided to indicate that the gesture is proper for activating the audio receiver before the audio receiver is actually activated.

15 Using the context variables of Tables 1-4, an application would determine whether to activate its audio receiver based on the HOLDING and DURATION context variable, the TiltAngleLR and TiltAngleFB context variables, and the Proximity or  
20 ProximityState context variables. In some embodiments, the sequence of recent values is used to determine a composite gesture, rather than just comparing instantaneous values.

As noted above, the activation of an audio  
25 receiver can be used when recording an audio message, when applying an audio signal to a speech recognition system or when transmitting a voice signal either across a computer network or through a cellular network. In addition, the activation of an audio

receiver can be made through a phone, or any hand held device that is capable of receiving audio signals.

It is thought by the present inventors that  
5 by eliminating the need to press an activation button, the user is able to concentrate more on other tasks while speaking into the audio receiver. Thus, since the user does not have to concentrate on pressing and maintaining tension on a particular  
10 button, they are better able to concentrate on other tasks while speaking.

Although the above embodiment has been described in connection with activating an audio receiver, it may be generalized to starting other  
15 applications based on the mobile device being placed in an appropriate orientation for the application. For example, if the user is holding the device in an orientation that is indicative of listening to the device, an application that automatically plays voice  
20 mail could be activated. Another example would be answering a call on a cell phone: when the phone rings, the user picks it up and places it next to his or her ear to answer the call. Because of the sensed gesture, there is no need to perform secondary  
25 preparatory actions to answer the call (such as pressing a TALK button or opening a flip-top cover). Such preparatory actions are unnecessary under the present invention and as such the present invention

eliminates extra steps that may be distracting or unfamiliar to the user.

#### CHANGING DISPLAY ORIENTATION

In other embodiments of the present invention, the tilt sensor is used to detect the orientation of the mobile device so that the image on the display of the mobile device may be matched to the mobile device orientation.

FIG. 10 provides an example of a mobile device 1100 in an upright orientation. In FIG. 10, the present invention displays an image 1102 of a set of text in a portrait orientation to match the orientation of mobile device 1100. FIG. 11 shows the same mobile device rotated counterclockwise 90°. Under the present invention, this rotation is sensed by the tilt sensors and in response, a new image 1104 of the set of text is displayed. In particular, image 1104 shows the text in a landscape view to match the new orientation of mobile device 1100.

Under the present invention, the displayed image may be matched to the orientation of the device through a simple rotation of the display image or through a redrawing of the display image based on the orientation of the device and the relative dimensions of the display in that orientation.

A simple rotation is typically performed by using the center of the screen as the center of rotation. For such rotations, a transform of points

x,y in the document to a point x',y' on the screen is given by equation 3:

$$m = T \cdot R \cdot T^{-1} \quad \text{EQ. 3}$$

5

where T is a translation and R is the 2D rotation matrix for 0°, 90°, 180°, or 270°.

A redrawing of the image that takes the dimensions of the display into consideration allows applications to change the contents of the image before redrawing the image. For instance, a word processing application can recalculate word wrapping based on the dimensions of the display in its new orientation. Thus, the number of words per line will change when the image is drawn in its new orientation. An example of this effect can be seen by comparing the text in image 1102 to the text in image 1104.

Context information server 800 causes the image to be refreshed by sending an appropriate notification to applications 802. These applications then generate a new image for the display.

To determine the orientation of the mobile device, most embodiments of the present invention examine both the left/right tilt of the mobile device and the front/back tilt. FIG. 12 provides a graph showing the orientations determined by context information server 800 for various combinations of left/right and forward/back tilt. In FIG. 12,

left/right tilt is shown along horizontal axis 1300 and forward/back tilt is shown along vertical axis 1302. In FIG. 12, there are four orientation regions 1304, 1306, 1308, and 1310, which are separated by  
5 deadbands 1312, 1313, 1314 and 1315. FIG. 12 also includes a flat area 1316, that corresponds to the mobile device being laid flat.

Orientation area 1304 is related to an upright portrait orientation for a mobile device such  
10 as mobile device 1100 of FIG. 10. This is the typical or natural way for a user to hold the mobile device. Orientation areas 1308 and 1310 are associated with a rotation of the mobile device counterclockwise and clockwise 90°, respectively. Orientation area 1306  
15 is associated with the mobile device being rotated 180° so that is upside down.

Transitions between these areas nominally occur when the left/right tilt equals the forward/back tilt. As shown by deadbands 1312, 1313,  
20 1314 and 1315, the display does not switch immediately at these angles. Instead, there is a plus or minus 5° deadband to prevent jitter. Thus, the device must tilt through the entire deadband zone before context information server 800 of FIG. 8 will  
25 issue a new orientation value. In some embodiments, there is a further 0.5 second time-out. The orientation of the device must remain at the new orientation for 0.5 full seconds before the display format changes.





device is not being held, context information server  
800 searches through FIFO 806 to find the most recent  
stable orientation other than flat. An orientation  
is considered stable if it was maintained for more  
5 than 1 or 2 seconds. This stable orientation is then  
selected as the orientation to be used while the  
device remains flat.

#### TILT SCROLLING

Under embodiments of the present invention,  
10 a user can scroll through a displayed document,  
spreadsheet, or image, simply by tilting the input  
device. In most embodiments, the user indicates  
their desire to use tilt scrolling by touching the  
touch pad on the bezel of the mobile device.  
15 Although in the embodiments discussed below, a touch  
sensor is used to indicate a desire to begin tilt  
scrolling, other inputs can be used within the scope  
of the present invention to indicate that the user  
wishes to begin tilt scrolling.

20 Under one embodiment of the invention, when  
the user indicates that they wish to begin tilt  
scrolling, the mobile device captures the current  
forward/back tilt and left/right tilt and uses these  
tilt angles as the starting orientation for the  
25 device. The direction and speed of scrolling is then  
determined relative to this starting orientation.

By capturing this starting orientation, the  
present invention keeps the displayed image from  
scrolling until the user tilts the device from its

initial position. This makes the scrolling behave in a more predictable manner and is different from prior art tilt scrolling devices. In prior art devices, the direction and speed of the scrolling is  
5 determined relative to tilt angles of zero or tilt angles that the user must set using a separate command to "recenter" the device. As such, the device will begin to scroll immediately if the device is tilted when the user indicates that they want to  
10 activate tilt scrolling. The present invention improves on the use of a "recenter" command by combining recentering with the initiation of scrolling (i.e. as soon as the user touches the bezel to start scrolling, this also resets the starting  
15 angles for the tilt).

Under the present invention, the rate and direction of forward/back scrolling is related to the angle of forward/back tilting by:

$$v_{fb} = k \cdot \text{sgn}(dA_{fb}) \cdot \max(\|dA_{fb}\| - dA_{\min}, 0)^\alpha \quad \text{EQ. 4}$$

20 where  $v_{fb}$  is the calculated velocity for the forward-backward scrolling,  $k$  is the control gain,  $dA_{fb}$  is the change in the forward/back tilt angle relative to a beginning orientation,  $dA_{\min}$  is the size of a dead band, and  $\alpha$  is a non-linear parameter. Under one  
25 embodiment,  $k=.2$ ,  $\alpha=1.6$  and  $dA_{\min}=1^\circ-4^\circ$ . A similar equation is used to determine left/right scrolling based on left/right tilt angle.

The scrolling control can be single axis where the device examines the left/right tilt and the

forward/back tilt and only scrolls along the axis with the larger tilt angle. Thus, if the relative forward/back tilt is larger than the relative left/right tilt, the image is scrolled based only on the forward/back tilt. Alternatively, the scrolling control may be mixed exclusive axis, where a square dead band is applied around the zero tilt point, such that small tilts are ignored. For instance, if a user tilts the device a small amount forward but a large amount left, the image will only scroll left. However, if the user increases the forward tilt, the image will scroll diagonally. Lastly, the scrolling control can be a dual axis control in which both forward/back tilt and left/right tilt are used at the same time to scroll the image without a dead band.

Under one embodiment of the present invention, tilt scrolling is combined with the orientation matching described above. This represents a significant challenge since both techniques utilize the tilting of the device for changing the display.

Under the present invention, once scrolling has been initiated, the tilt of the device is only applied to the scrolling and is not used to change the orientation of the display. Thus, tilting the mobile device will not cause the orientation to switch until scrolling is deactivated.

The application that is controlling the scrolling helps to enforce this rule by posting a

scrolling value with Context Information Server 800. This value is shown in Table 4. Once this value is posted, Context Information Server 800 suspends updates to the DISPLAYORIENTATION value until  
5 scrolling has stopped.

In addition, when the user releases the scrolling button or the scrolling touch sensor, the system does not automatically change the orientation based on the current tilt. Instead, the system  
10 allows the user 1 or 2 seconds to return the mobile device to the position it was in when scrolling was initiated. After that waiting period, the orientation of the image is changed to match the orientation of the mobile device.

15        SCROLLING WITHOUT MENU BAR AND START BAR

In many applications, a displayed document is shown with banners that provide menus, scroll bars, and/or command icons. Under one embodiment of the present invention, the inventors have discovered  
20 that users do not need the command menus or the command icons during scrolling. Thus, under one embodiment of the invention, applications remove their menu bars and command bars from the display during scrolling. Note that this invention is not  
25 limited to mobile devices and may be used on any computing system or with any type of mobile device. By removing the menu bars or command icons, more screen area is available for showing the image that

is being scrolled. This makes it easier for the user to find the information they want.

The removal of the command bars during scrolling is independent of tilt scrolling. In other words, the aspect of removing command bars may be practiced regardless of how the scrolling is initiated.

Under one embodiment, the input used to remove the menu bars and command icons is the same as that used to initiate scrolling. For example, in a tilt scrolling application, the menu bar and command icons disappear as soon as the user presses the button or touch sensor that indicates that tilt scrolling is to be initiated. Under such embodiments, a larger dead zone from the zero orientation angle may be needed to ensure that the image does not scroll when the user just wants to view the full screen.

#### Selective Display of Toolbars

Under some embodiments of the present invention, several touch sensors are provided on the mobile device. For a given application, each touch sensor is associated with a different toolbar. When the user is touching a particular touch sensor, its corresponding toolbar is displayed. However, when the user is not touching the touch sensor, the toolbar is hidden so that more of the document or image may be displayed. In some embodiments, the touch sensor may be associated with an entire

application (rather than just a toolbar) so that the user may switch applications temporarily by maintaining contact with the touch sensor. In this case, further interaction with the application using  
5 the stylus (touch-screen) causes the switch to become permanent.

#### Display Contrast Adjustment

One problem encountered when using a tilted liquid crystal display is that as the display is  
10 tilted away from the user, the contrast of the displayed image is lessened. The present invention improves the displayed image by increasing the contrast of the display as the user tilts the display away from them. Note that this aspect of the present  
15 invention is not limited to personal information managers and may be used with any LCD device such as a pager, watch, laptop computer, cell phone, or stand alone LCD display. Under one embodiment, the contrast is set according to the following equation:

20

$$\text{contrast} = m \cdot dA_{fb} + b \quad \text{EQ. 5}$$

where m is a constant equal to -.135, b is a constant equal to 5.25,  $dA_{fb}$  is the change from the ideal  
25 viewing angle as measured by a tilt sensor in the display, and "contrast" is the change in the contrast setting. Note that these values correspond to the software contrast settings of 1-10 available on the Cassiopeia E105 device. To prevent hysteresis, a tilt

angle change of more than  $3^\circ$  is typically required before the contrast is adjusted.

#### POWER MANAGEMENT

Under one embodiment of the present invention, a mobile device places itself in a full-power mode based on how the device is being handled. In one particular embodiment, the invention uses a combination of sensors to determine whether the user wants the device to be in full-power mode. In particular, the system uses a touch sensor to determine whether the user is holding the device and a tilt sensor to determine whether the user has properly oriented the device so that it is likely they are looking at it. By using both a touch sensor and an orientation sensor, the present invention avoids placing the device in full-power mode when it is in a briefcase.

In one particular embodiment, the orientation for full-power mode is a left/right tilt of between plus or minus  $15^\circ$ , a forward/back tilt of greater than  $-5^\circ$ , and an upright portrait orientation. If the user maintains this orientation for at least .5 seconds, PIC microprocessor 252 of FIG. 1 places the device in full-power mode using power switch 280. The required time interval can be set as desired but is used to prevent powering up due to transient signals.

In other embodiments, the present invention prevents a mobile device from entering an idle mode



if the user is handling the device or gesturing toward the device. In idle mode, the mobile device reduces the power consumption of the device by turning off the display. Typically, a mobile device  
5 will enter idle mode if the user has not pressed a button or touched the screen for some period of time. Under certain types of usage, users find that the system powers down when they would rather have it remain active. For instance, this often happens when  
10 the user is reading a large amount of text or is trying to interact with someone else while periodically relating to the text.

Under one embodiment of the invention, the device is prevented from entering an idle mode when  
15 context information server 800 determines that the user is holding the input device or when it determines that there is motion near the device. Such motion can be detected by changes in the output of the proximity sensor and is indicative of a user  
20 gesturing toward the device.

Note that this embodiment relies on motion and not just proximity. This is done to allow the device to enter idle mode when it is placed near a fixed object while it is not being used. For example,  
25 under the present invention, the device will still enter idle mode if a stack of paper is placed on top of the device.

Although the present invention has been described with reference to preferred embodiments,

workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

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